

SOUTHERN RESIDENT KILLER WHALE SYMPOSIUM PROCEEDINGS

HOSTED BY:

NORTHWEST FISHERIES SCIENCE CENTER
WASHINGTON DEPARTMENT OF FISH AND WILDLIFE
DEPARTMENT OF FISHERIES AND OCEANS CANADA

SUMMARY REPORT

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NORTHWEST FISHERIES SCIENCE CENTER
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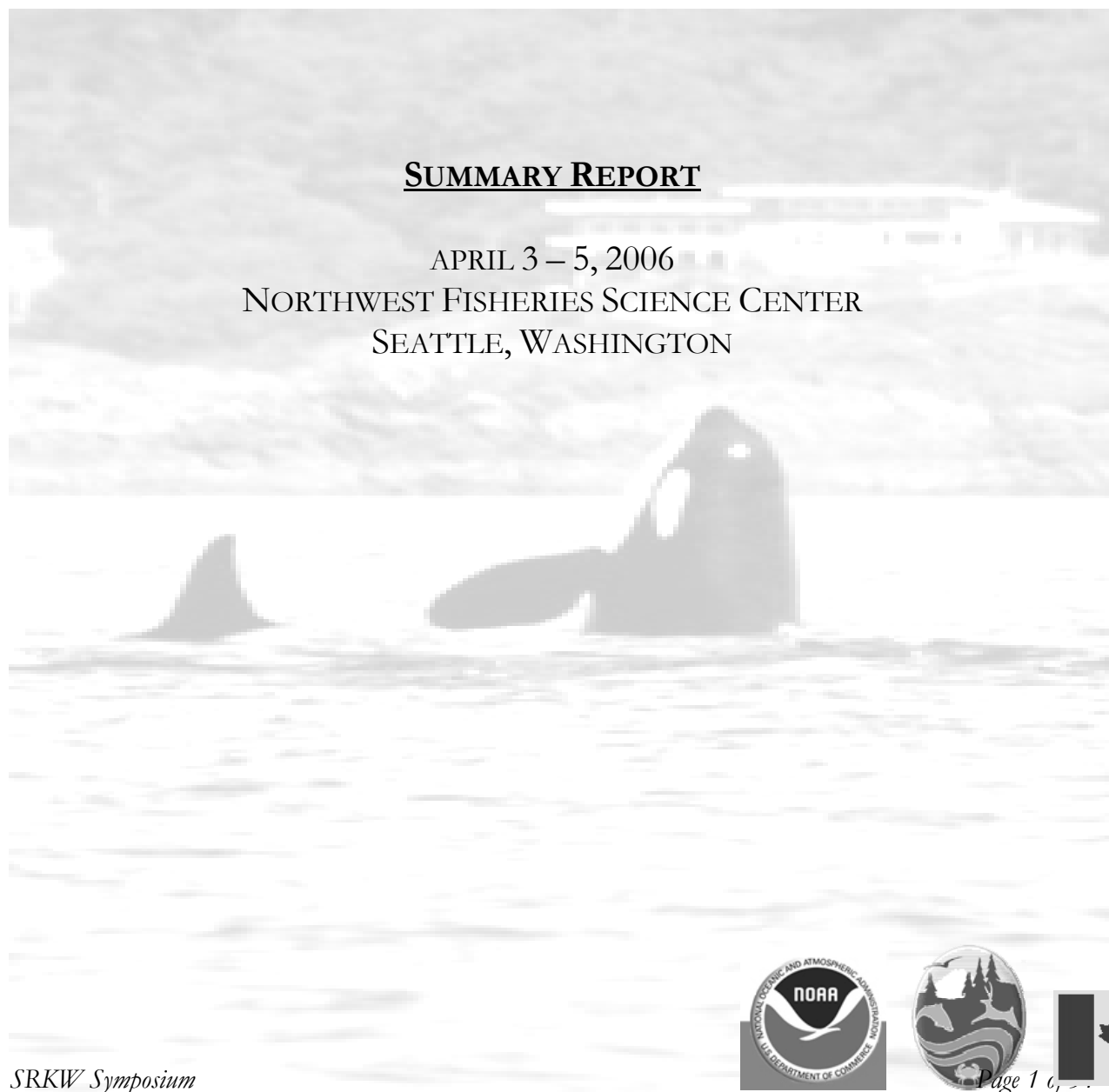


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I. SYMPOSIUM OVERVIEW

In response to the significant population decline of the Southern Resident killer whales (SRKW) over the past decade, this population was listed as endangered under Canada's Species at Risk Act in 2001, by Washington State in 2004, and under the U.S. Endangered Species Act in 2006. In a continued effort to better understand the risk factors contributing to the SRKWs' decline, and to coordinate efficient and effective bilateral management and conservation of the species, the Northwest Fisheries Science Center (NWFSC) partnered with the Washington Department of Fish and Wildlife (WDFW) and the Department of Fisheries and Oceans Canada (DFO) to host an international Southern Resident Killer Whale Symposium on April 3-5, 2006 in Seattle, Washington. The partners engaged the neutral facilitation services of RESOLVE, a non-profit organization based in Portland, Oregon, to assist with planning and facilitating the symposium.

The symposium provided an opportunity for representatives from a variety of agencies, universities, and organizations to collaboratively address the following symposium objectives:

1. Present new research results;
2. Examine how this information moves us forward in informing conservation actions; and
3. Discuss what additional research, if any, is needed.

Approximately 200 participants worked to achieve these objectives throughout the course of the three-day symposium. Each participant was provided with an agenda and a bound collection of research abstracts pertaining to the presentations. Opening remarks were provided by Kurt Beckett, Chief of Staff for Senator Maria Cantwell, and Drs. Linda Jones and Usha Varanasi of NWFSC. Garth Griffin, NOAA Fisheries' NW Regional Office, Rocky Beach, WDFW, and Marilyn Joyce, DFO, each outlined their respective agencies' recovery plans and research and management needs. An electronic version of this report, the symposium agenda and abstracts and the participant list will be made available at:

www.nwfsc.noaa.gov/research/divisions/cbd/marine_mammal/marinemammal.cfm.

Dr. Michael Ford of NWFSC provided an overview of high priority research questions developed during three previous SRKW workshops held in May 2003 and January 2004 co-sponsored by the three agencies. These high priority questions were used by the NWFSC to help direct their own research efforts and their funding of research conducted by other organizations. Since 2003, Congress has provided approximately \$4M to NOAA Fisheries Service to conduct and fund research on SRKW. The symposium was held in part to highlight some of the research that has been conducted using these funds. Presentations of research wholly or partially funded by NOAA Fisheries are noted with an asterisk (*) in the report. The symposium offered eight individual sessions focused on answering these high priority research questions for each of the following topics:

- Genetics
- Population dynamics
- Contaminants
- Prey
- Energetics
- Distribution and habitat

- Vessel traffic
- Noise

Each session began with a series of presentations of recent research results by eminent scientists in related field(s), followed by an open discussion between presenters and the audience. The conversations were focused on three overarching questions:

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

The majority of the symposium's third and final day was dedicated to a roundtable panel of experts' reflections on information presented throughout the symposium from within the context of their particular area of expertise, and focused on addressing a set of discussion questions. Panel members were provided the opportunity to respond to each others' comments before the deliberations opened up to all symposium participants.

A report summarizing the symposium discussions is detailed below. The report is organized session-by-session and follows the temporal sequence of topics reflected in the symposium agenda. The purpose of the report is to summarize the content of the symposium. As such, it does not necessarily reflect the views or policies of any of the sponsoring agencies. In describing the discussion that occurred at the symposium we provide where possible the names of the persons contributing to the discussion. Although we have attempted to accurately summarize the discussions that occurred, we doubt that every speaker's contributions were captured perfectly. Therefore, this report does not necessarily reflect any particular person's views, even if they are mentioned by name.

II. SESSION SUMMARIES

A. GENETICS

Presentations[†]

- * Michael Ford, NWFSC – Killer whale taxonomy and “species” status under the Endangered Species Act
- * Phil Morin, Southwest Fisheries Science Center – Genetic analysis of killer whale (*Orcinus orca*) historical bone and tooth samples to identify western U.S. ecotypes
- * Phil Morin, Southwest Fisheries Science Center – On the use of AFLP markers for taxonomic study of killer whales (presented for R. LeDuc, N. Hedrick, and R. Pitman)
- * Rus Hoelzel, University of Durham – Evolution of population genetic structure of killer whales (*Orcinus orca*) in the North Pacific

High Priority Research Questions

- *Are the North Pacific resident killer whales a distinct species or subspecies?*
- *What are the patterns of mating within the Southern Residents, and between the Southern Residents and other eastern North Pacific killer whale populations? Are intrinsic demographic problems, such as a lack of appropriate mates or inbreeding depression, limiting the Southern Resident’s recovery?*
- *What was the historical size of the Southern Resident killer whale population? Is there genetic evidence that the Southern Resident’s have experienced a severe genetic bottleneck?*

Genetics Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Michael Ford)

Dr. Michael Ford initiated the discussions by expressing excitement about the current efforts to develop models to allow more accurate estimates of times of population divergence and rates of gene flow among populations than have been available in the past. He also cautioned participants to keep the following limitations of the models in mind:

- Mitochondrial DNA is maternally inherited, and therefore cannot be used to infer patterns of male-mediated gene flow;
- Microsatellite DNA markers are hard to model given the high rate of genetic mutations; and

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- Population genetic models inevitably make some unrealistic assumptions, and the sensitivity of the results to these assumptions should be evaluated.

Dr. Ford suggested ground-truthing study results through further developed simulations and exploring new markers in an effort to move beyond current modeling limitations.

Presenter Responses to Participants' Questions

A question was raised around whether the rates of gene flow estimated by Drs. Hoelzel and Hey would affect the previous determination that the SRKW population is a “distinct population segment” for the purpose of ESA listings. Dr. Rus Hoelzel responded that while genetic migration does occur, it is small; on the order of one inter-population mating occurring every five to ten years. Dr. Hoelzel characterized the population structure of killer whales globally as one in which every local population is distinct but the absolute level of differentiation is not large and low levels of gene flow among populations occurs. He concluded that estimates of F_{ST} (a measure of the departure from random mating caused by population structure) are consistent with this scenario, keeping in mind that killer whales are uniquely and coherently social animals with local populations developing through extensions of family lines/clans. He also noted that when evaluating patterns of genetic variation within and among killer whale populations, it is essential to keep their social biology in mind. In particular, killer whales are characterized by an unusual population structure with local populations developing through extension of family lines/clans that may ultimately grow to form discrete populations. This type of social structure will tend to produce large numbers of relatively discrete populations but may not lead to large scale divergence globally.

One audience member asked about the seemingly problematic result that model estimates indicated that populations from Puget Sound and Iceland were connected by gene flow. Dr. Hoelzel noted that the estimate of migration rates between Iceland and Southern Resident populations presented a great challenge for the model whereas an analysis of proximate populations is more realistic for the model and yielded more reliable results. He also noted that Puget Sound and Iceland killer whales could conceivably be connected by gene flow via intermediary populations, and the model does not explicitly take this into account. He also noted that the Hay-Nielson model that he used allows you to test for isolation and results suggest North Pacific isolation occurred approximately 10,000 years ago.

A participant inquired if the size of the Southern Resident population which existed prior to European contact could be determined using these or other genetic methods. Dr. Hoelzel replied that it is possible. The model assumes that an ancestral population of constant size divides into two descendent populations, each of constant size. The estimates of the ancestral population size that Dr. Hoelzel obtained were consistent across different pairs of populations, and indicated a very large ancestral size. Dr. Hoelzel noted, however, that this may not imply that the populations have changed size but could instead be an artifact of the two-population assumption made by the model. If in fact there are many populations, the model may be estimating the ancestral size of the combined group of populations (i.e., perhaps the worldwide population size) rather than the immediate ancestral population of the two populations sampled.

Dr. Hoelzel noted that there may be other methods of detecting changes in population size that may be more effective than the particular model he used which is focused more on estimating divergence time and gene flow.

A concern was raised regarding the rigor of the genetic migration modeling based on the assumption of a single ancestral population and only two descendant populations (see above). Dr. Hoelzel acknowledged that it is important to consider alternative hypotheses to test where populations came from and how they are related due to gaps in the current information available. He noted, however, that all models have some unrealistic assumptions but the results from these models can still be useful. Dr. Hoelzel stated that since the various different approaches to modeling genetic migration among killer whale populations produce very similar results, the models and their assumptions can be refined further but will not likely produce drastically different results. He also agreed that the assumption of a single ancestral population is not accurate, but reinforced that regardless of this less useful aspect of the model the migration rate estimates appear to be reasonable.

In response to the question of whether or not genetics research could determine if killer whale populations (especially the southern resident population) had more extensive ranges historically, Dr. Phil Morin replied that it is possible but more samples would be required. He also reiterated the fact that nuclear samples are very hard to obtain from older bone samples, which will limit the usefulness of the older DNA samples. Dr. Hoelzel noted, however, that although ancient and historic DNA samples are hard to obtain, work is being done to develop nuclear variables and to apply them to historic and modern samples using SNPs (single nucleotide polymorphisms -- variations in the DNA which make every individual unique).

Dr. Ford summarized the following key points of the session discussions:

- We now have a better understanding of rates of gene flow among populations, although additional validation of the model results will be needed;
- The study results can help set expectations for recovered killer whale populations. For example, a small population of 80-100 animals will be more viable with low levels of gene flow than if completely isolated;
- It will be important to conduct additional studies to evaluate patterns of paternity within and among pods;
- If available, it would be useful to analyze more historical genetic samples.

A final question was raised regarding the adoption of a quantitative standard for determining Distinct Population Segment (DPS) status. Dr. Ford replied that although there have been some published conservation unit criteria that are strictly quantitative, NOAA Fisheries has generally preferred to use broader criteria for determining DPS status. Decisions are then made by an expert biological review team, using the best science available to make an informed decision based on all of the available information. When asked if he thought a standard(s) should be established, Dr. Ford suggested that there would be a trade off between being inclusive and using a variety of information sources in a somewhat subjective way versus using more limited data in a strictly quantitative, and perhaps arbitrary, way. He concluded that biodiversity is hierarchical and there are many biologically appropriate ways to identify reasonable conservation units.

B. POPULATION DYNAMICS

Presentations[†]

- * Eli Holmes, NWFSC – Southern Resident killer whale population dynamics and population viability analysis (presented for P.R. Wade and K.C. Balcomb III)
- Peter Olesiuk, Fisheries and Oceans Canada – Life history and population dynamics of resident killer whales (*Orcinus orca*) in British Columbia and neighbouring waters
- * John Durban, Alaska Fisheries Science Center – Long-term social dynamics of fish-eating killer whales

High Priority Research Questions

- *What is the population growth rate of Southern Residents and what causes variation in the rate from that of Northern Residents?*
- *What factors are affecting the reproductive success of SRKWs?*
- *What are the factors affecting mortality?*
- *Do changes in the social structure affect the population's ability to recover?*

Discussion Questions

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Eli Holmes)

In an effort to help answer the question regarding population growth rate of Southern Residents and variations in this rate from Northern Residents, Dr. Eli Holmes proposed attention be directed to identifying what drives population responses during good and bad years given the evidence of cyclical patterns. She indicated the analyses by Dr. Peter Olesiuk and Dr. Paul Wade (which was presented by Dr. Holmes) have shown that there are long-amplitude cycles in mortality and fecundity of Southern and Northern Residents. While it is possible to identify the drivers of these cycles through strong correlative studies, Dr. Holmes reminded the audience that the factor driving cycles in SRKW is not necessarily the causal factor of the decline. Resident killer whales eat a prey, Chinook, whose life-history is such that it undergoes large boom-bust spawner cycles. Cyclical mortality and fecundity rates are expected. Dr. Holmes encouraged researchers to assess why the lows are so low, and to identify mitigating factors that contribute to overall stress on the populations. It may be difficult to tease out these mitigating factors but it is possible using comparative studies, specifically comparing mitigating factors in the Southern versus Northern

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Residents which also experienced periods of lower survivorship but experienced lows that were not as low as in the Southern Residents.

One of the data gaps brought up during discussions following Dr. Olesiuk's presentation was what was happening to the Northern, Southern, and Alaskan Residents before the mid-1970s. All three experienced a period of steady growth into the 1980s. This was especially pronounced in the Alaskan and Northern Residents. Are all three recovering from some large reduction in abundance or did all experience an increase in 'carrying capacity'? The answer to this question is important to answering the question of what is the historic population size and structure. To help fill in this data gap, Dr. Holmes suggested that examining older individuals can hold clues to the period before monitoring. Specifically, the age-structure of the older individuals may hold evidence of a missing cohort or evidence of some severe population perturbation. Therefore, further research focused on identifying ages and analyzing fecundity of older individuals could significantly contribute to answering this outstanding question.

The following key questions, yet to be answered, were identified by Dr. Holmes:

1. Why has the Southern Resident population been hit harder? Is it because the factor driving the cycles was worse or is there some additional factor that made the SRKW more susceptible to the lows in this factor?
2. What are Alaskan and Northern Resident populations recovering from?
3. What is a sustainable population abundance of Southern Residents?

Dr. Holmes encouraged the study of population dynamics and stressors to help inform management decisions. For example, management plans should be tailored to conserving a defined sustainable population; differing significantly if the conservation goal is 100 killer whales versus a much larger population. Dr. John Durban added that science needs to be closely linked to observed changes so management efforts can be conducted in the spirit of experimentation and informed by the best available science as it is developed over time.

Presenter Responses to Participants' Questions

The seemingly incongruent relationship between the current growth of killer whale populations and the steady decline of Chinook salmon stocks was pointed out by a participant. Dr. Holmes suggested it could be that recent conditions, while poor, have been acceptable for killer whales' needs. Dr. Holmes proposed it would be more useful to investigate why SRKW survivorship was so low between 1994 and 2002 relative to NRKWs; keeping in mind that mortality cannot be attributed to just one factor, such as prey abundance.

Dr. Durban interjected that killer whales may experience a lag time in catching up with increases in salmon abundance. He suggested that long term trends should be considered when analyzing the Puget Sounds' carrying capacity and proposed that historic populations of Southern Residents were likely larger than today due to historically larger ranges and greater abundance of salmon stocks.

Dr. Peter Olesiuk remarked that the demographic approach tries to account for changes in population composition in response to a question about what, if any, internal drivers affect mortality rates. He noted that populations with large numbers of older males have higher mortality rates and populations with large numbers of older females have lower mortality rates. Research has identified

areas of concern to explore further to determine how much of an affect external and internal factors have on population dynamics.

In closing, Dr. Olesiuk suggested it is natural for populations to experience long periods of steady growth punctuated by extreme mortality and proposed that further research should examine mortality and fecundity during these times. Dr. Olesiuk noted that declines in Southern Residents were very rapid while recovery will necessarily be very slow given their limited maximum reproductive output. Dr. Holmes added that we should not assume that 100 Southern Residents is not a sustainable population; but rather that 100 individuals -- combined with the periods of severely low survivorship and low fecundity experienced over the last 30 years -- is not sustainable. 100 individuals may well be sustainable with mortality and fecundity more like that experienced in the North. As such, it is important to: 1) use a model to predict population responses; and 2) track age structures to evaluate impacts of management decisions over time.

C. CONTAMINANTS

Presentations[†]

- Peter Ross, Fisheries and Oceans Canada – Persistent organic pollutants in marine mammals inhabiting the transboundary waters of British Columbia-Washington
- * Gina Ylitalo, NWFSC and Sandie O'Neill, WDFW – Regional patterns of persistent organic pollutants in five Pacific salmon species (*Oncorhynchus* spp) and their contributions to contaminant levels in northern and Southern Resident killer whales (*Orcinus orca*)

High Priority Research Questions

- *What are the differences in levels and patterns of contaminants among the Southern Resident pods, as well as differences between Southern Residents and other eastern North Pacific killer whale populations?*
- *Is there a relationship between exposure to contaminants in Southern Resident whales and their survivorship or reproductive success?*

Contaminants Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Peggy Krahn)

Dr. Peggy Krahn commented on the importance of biopsy samples of killer whales in answering the high priority questions on contaminants and prey, adding that sufficient recent data on the Southern

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Residents simply do not exist. To address the critical information gaps, she noted that new samples of whale tissues are needed to analyze for current and emerging contaminants in the whales and for comparison of contaminant levels and patterns among the pods and between the Southern Residents and other killer whale populations. In addition, Dr. Krahn stated that a lot of good information on contaminant levels in prey species is available from the research presented by O'Neill and Ylitalo and can be used to help assess foraging preferences of the Southern Residents once data are available from their biopsy samples.

Dr. Peter Ross observed that biopsies are a controversial strategy and that alternatives are being explored. He stated that we have learned a lot about contaminants and habitat health by looking at Chinook, other residents and transients, and harbor seals and that he was heartened by the degree to which we do understand temporal and emerging trends, point source contaminants, and killer whale habitat quality. A temporal model suggests that PCB levels have declined in killer whales by about 2.5-fold since 1970, but PBDE studies in other species suggest an exponential increase in the levels of these flame retardants in the region. It was noted that recent samples would provide an update to previous studies (using samples from killer whales collected in 1993-96), although such temporal changes are less detectable in a long-lived species like the killer whale.

Presenter Responses to Participants' Questions

In response to a question regarding effects on different pods or populations of killer whales, Dr. Ross noted that individual variations within pods may confound results (especially when sample size is small). He added that the quality of databases for populations differs in frequency and number of sightings, making it difficult to evaluate inter-population differences in demographics. He suggested that there is a need to build a weight of evidence using biological surrogate species, demographics and biomarkers to guide regulators and convince industry leaders to reduce their release of these chemicals. Dr. Krahn stated that a lot of data exists for global populations of killer whales which can provide perspective for future data from Southern Resident population.

The final question focused on whether or not contaminant signals could be correlated directly to what prey killer whales consume. Ms. Sandie O'Neill replied that theoretically, you should be able to see a correlation between level and patterns of contaminants in killer whales and their prey, however, the degree of correlation will be influenced by the regional distinctiveness of contaminant patterns of the prey and the feeding ranges of the whales. The more the feeding ranges of northern and southern killer whales overlap, the more difficult it will be to isolate distinct patterns in whales that can be correlated with regional patterns observed for prey. Furthermore, how contaminants are metabolized by whales may obscure our ability to correlate levels and patterns of contaminants between whales and their prey.

D. PREY

Presentations[†]

- John Ford, Fisheries and Oceans Canada – Selective foraging in resident killer whales
- * Shannon McCluskey, University of Washington – Movement patterns and population trends of Southern Resident killer whales in relation to relative abundance and distribution of Pacific Salmon in the Puget Sound – Georgia Basin
- * Peggy Krahn, NWFSC – Feeding ecology of eastern North Pacific killer whales *Orcinus orca* from fatty acid, stable isotope and organochlorine analyses of blubber biopsies
- Brad Hanson, NWFSC – Investigations of associations of southern resident killer whales and their prey
 - * Mapping areas of potential prey of killer whales in Puget Sound: A pilot study (presented for J.K. Horne and S. Gauthier)
 - * Diving behavior of "southern resident" killer whales in the trans-boundary waters of British Columbia and Washington: Implications for foraging ecology
 - * Focal behavioral observations and fish-eating killer whales: Improving our understanding of foraging behavior and prey selection
- Jeff Haymes, WDFW – Washington Chinook Salmon abundance (B.Sanford)
- John Ford, Fisheries and Oceans Canada – Linking prey and population dynamics: did food limitation cause recent declines of resident killer whales?

High Priority Research Questions

- *What are the important prey species for SRKW's?*
- *Is prey abundance adequate to support SRKW populations?*
- *Is the quality of the prey adequate to meet the nutritional and energetic needs of killer whales?*

Prey Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. John Ford)

Dr. John Ford began by expressing his excitement in seeing various research perspectives, such as population dynamics and contaminants, demonstrating ecotypic-level evidence of preferred killer whale prey; such correlations significantly support a limited field of evidence on important prey.

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As a species, killer whales are generalists consuming approximately 150 species of prey worldwide. Yet local populations have highly specialized diets that appear to be determined by learning and cultural transmission, and which appear to be retained even when confronted with a decline in the abundance of preferred prey. Dr. Ford expressed his hope for current research efforts focused on predator-prey interactions to clarify how flexible this specialization is and to confirm whether or not killer whales can adapt their diet if needed. Such research is also needed to better understand how killer whales locate and discriminate between different species of salmonids.

Presenter Responses to Participants' Questions

Given the Southern Residents' demonstrated preference for Chinook salmon, a participant inquired if it was possible to tease out the relative importance of hatchery Chinook versus wild Chinook stocks in their diet. Dr. Ford responded that current research is trying to assess this through genetic analysis of prey samples, but it is too early to say if killer whales exercise a preference for particular stocks of Chinook. Both wild- and hatchery-raised Chinook have been recorded as resident killer whale prey.

Regarding the question of what cues drive killer whales' decisions for movement, Dr. Brad Hanson commented that scientists do not have a good understanding at this point but suggested they may move to areas where fish are abundant. One goal is to conduct studies on winter movements of the Southern Residents to accumulate sufficient trends to explain prey relationships. Shannon McCluskey noted that the consumption of multiple-aged Chinook confounds results from studies of movement patterns in relation to relative abundance and distribution of particular year-classes of Chinook.

Dr. John Durban commented that it would be worthwhile to explore correlations between prey behavior and abundance of prey. He noted that Kim Parson's work weighs in on this dynamic but more studies are needed before drawing any conclusions. With respect to quantifying a sustainable killer whale population which the Puget Sound area can support, Dr. Durban suggested studying historic timing of salmon runs and geographical extent of killer whale populations, and then comparing that data with current conditions. A higher resolution of effects from changes in prey population abundance is very important to inform management decisions, but killer whale distribution during winter months and their prey requirements must be understood to fully assess such effects. The next steps are to identify the relative contribution of different salmon runs, determine if the whales switch prey in winter, and determine how many salmon are needed for killer whale prey.

In response to a question about the current inverse relationship between killer whale mortality and prey abundance, Dr. Durban replied it is difficult to estimate the extent of historical mortality due to wide-spread shooting of killer whales before long-term studies were initiated. He stated that it is possible the Southern Resident population was well below carrying capacity before studies began and we may be seeing evidence of a long-term recovery of a population that was well below carrying capacity.

Dr. Ford attributed much of the lack of information about where killer whales go in the winter and what they do to seasonally-inclement weather which makes it very difficult for research vessels to go out in the field. He suggested the use of remote acoustic recording devices to target areas along the

outer coast where we think killer whales are likely to be found. A prototype acoustic device deployed in the Queen Charlotte Islands has recorded numerous groups of northern residents in winter. He also wondered if a higher resolution of fatty acid analyses could help answer questions regarding winter data gaps.

Dr. Peggy Krahn responded that results would provide insight into their diet integrated over time, and signals would need to be separated from prey alone. Study results are in a quantitative stage right now and calibration factors regarding how predators metabolize fatty acids are needed in order to get to the qualitative stage. Quantitative results exist for pinnipeds but it is much harder to gather this information for cetaceans. Dr. Krahn proposed looking at predators that rely on one species of prey to get a handle on calibration factors.

In conclusion, Dr. Hanson stated that the probability of finding pods during winter months would be much higher using a combination of visual surveys and acoustic techniques. Current research efforts are getting much closer to putting the pieces of the puzzle together.

E. ENERGETICS

Presentations[†]

- Robin Dunkin, University of California, Santa Cruz – Seasonal variation in energetic status and body condition in killer whales
- * Samuel Wasser, University of Washington – Non-invasive monitoring of physiological health of Southern Resident killer whales

High Priority Research Question

- *Is the quality of the prey adequate to meet the nutritional and energetic needs of killer whales?*

Energetics Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Dawn Noren)

Dr. Dawn Noren stated that physiology and energetics of killer whales are difficult to study due to the large body size and free- ranging nature of these cetaceans. However it is important to monitor both because environmental and anthropogenic perturbations are capable of affecting health and/or daily metabolic expenditure in these animals. However, one confounding factor is that there is a lag time between changes in caloric intake and/or energy expenditure and effects on body condition.

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Although there are many caveats when studying captive animals, physiological and energetic measurements from captive animals are helpful in providing realistic baseline estimates for wild animals. To address data gaps, Dr. Noren suggested the application of emerging technologies that will enable the collection of physiological and energetic data from free-ranging killer whales. Future studies should also focus on the following:

- i. Comparing killer whale energetic requirements with prey availability.
- ii. Understanding the critical foraging periods and diet.
- iii. Determining appropriate measurements and techniques to assess body condition in free ranging killer whales.
- iv. Assessing factors that cause variation in body condition (blubber deposits).
- v. Understanding the frequency, duration, and effects of fasting.

Dr. Samuel Wasser suggested that to mitigate negative effects on killer whale physiology, the root of the problem(s) must be understood. Combined stressors are magnified to a greater degree than the sum of individual parts. For example, any form of disturbance may impact the immune system and makes the animals more vulnerable to effects from pathogens and toxins. Dr. Wasser proposed non-invasive research methods be applied to studying Southern Residents and expressed the hope that funding would become available to train scat detection dogs and conduct a pilot study of killer whale physiological health this spring.

Presenter Responses to Participants' Questions

In response to a question about killer whale energy reserves and capacity for fasting Robin Dunkin replied not much is known. Dr. Noren added that lipids in both blubber and protein in the body are burned during fasting so it is difficult to evaluate when durations of fasting are too long or frequencies of fasting are too often. A participant suggested procuring funding for energetics research through behavioral budgets. Dr. Noren replied that daily energetic costs in wild killer whales can be modeled by integrating behavioral budget data collected from wild killer whales during the vessel interaction studies and metabolic data collected from captive dolphins and killer whales during energetic studies. Dr. Wasser concluded by adding that many measurements are complimentary and collective knowledge will help address data gaps.

F. DISTRIBUTION AND HABITAT

Presentations[†]

- * Ken Balcomb, Center for Whale Research – Winter distribution of Southern Resident killer whales, 2003-2006
- * Jeff Nystuen, Applied Physics Laboratory, University of Washington – Listening for orcas in the underwater racket of Cape Flattery and Haro Strait
- * John Hildebrand, Scripps Institution of Oceanography, University of California, San Diego – Killer whale acoustic monitoring in the Coastal Waters of Washington

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- * Donna Hauser, University of Washington – Effects of environmental factors and temporal scale on pod-specific Southern Resident killer whale summer distribution patterns: implications for designating critical habitat

High Priority Research Question

- *What habitats are important for Southern Resident killer whales, particularly in outer coastal waters?*

Distribution and Habitat Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Brad Hanson)

Dr. Brad Hanson began the discussions by stating that summer information is used for Endangered Species Act critical habitat determinations however winter distribution data is a critical data gap. Visual identification of killer whales and their location are powerful measurements and set the standard for analyses, but new technologies are needed to collect data during the winter. Dr. Hanson proposed the application of acoustic monitoring as well as incorporation of biological and oceanographic information and modeling in future studies.

Presenter Responses to Participants' Questions

A participant inquired about the relative cost of acoustic technology compared to vessel research given existing budget constraints. Dr. Hanson noted that the estimated base cost to operate a NOAA vessel is \$20,000/day. In addition, monitoring the towed acoustic array from a NOAA vessel would cost approximately \$2000/day for staff. He also estimated costs for moored passive acoustic instruments at \$10,000 each, however research and development, moorings and deployments, analyses, overheads, etc. typically push costs closer to \$50,000/instrument. Dr. John Hildebrand added that acoustics systems provide continuous observations and that a more accurate comparison would be two to three vessel days versus approximately six months of acoustic data. Dr. Jeff Nystuen stated hydrophone technology is becoming more affordable. Dr. Hanson pointed out that both approaches have inverse spatial and temporal limitations; acoustic recorders being limited spatially but not temporally and vessels with towed arrays being limited temporally not spatially.

Dr. Hildebrand declared that acoustic data sets hold great untapped potential. Data are currently used to identify presence or absence of targets but could also be used to identify individual killer whales by their calls. A participant inquired if winter storms would create substantial interference in acoustic monitoring recordings. Dr. Nystuen responded studies in the Bering Sea indicated animals' calls got louder during storms and an increase in bubbles effectively buffered sounds from the storms above.

In closing, Dr. Hildebrand suggested there is great value in using a two-pronged approach with both visual and acoustic monitoring techniques in answering the following questions: 1) where are they? and 2) what are they doing in various habitats in the outer coastal waters?

G. VESSEL TRAFFIC

Presentations[†]

- * Dave Bain, University of Washington – Land-based studies of the effects of vessel traffic on the behavior of Northern and Southern Resident killer whales (*Orcinus spp.*)
- * Dawn Noren, NWFSC – Behavioral energetics of Southern Resident killer whales in the presence of vessels
- * Jim Ha, University of Washington – Social behavior of Southern Resident killer whales (*Orcinus orca*)

High Priority Research Question

- *Does vessel presence affect Southern Resident killer whales?*

Vessel Traffic Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Dawn Noren)

Dr. Dawn Noren summarized the presentations stating the three different studies and approaches showed some effect of vessels on Southern Resident killer whales, but that relationships between various impacts are very complicated. Future work includes additional data analyses and research on how the mode of vessel operation and the distance between vessels and whales affects the whales' behaviors.

Presenter Responses to Participants' Questions

A participant noted there appeared to be a preliminary correlation between perceptible impacts and the presence of ≤ 15 vessels and wondered if data suggested correlations between impacts and the vessels' distance from killer whales. Dr. Noren replied that her data for 2005 needs to be analyzed to begin to answer that question. Dr. Dave Bain added his data includes vessel distances but analyses are still being conducted.

[†] Only individuals presenting the papers are listed; please see the abstracts for a full list of authors.

* Indicates research wholly or partially funded by NOAA Fisheries.

With respect to research assessing vessel interactions with killer whales at night Dr. Bain stated the equipment to conduct research at night is very expensive and video does not provide high enough resolution. In his opinion, daytime observations provide a solid baseline for analysis.

When asked if study results indicated varying degrees of impacts between motorized and non-motorized vessels Dr. Bain replied kayaks seemed to startle the killer whales more as a result of their ability to reach closer proximities before being detected. Dr. Noren added that kayaks tend to remain close to shore and are able to approach whales traveling along the shoreline while motorized boats that follow Be Whale Wise Guidelines remain on the offshore side of whales when whales are traveling close to shore. Dr. Noren also stated that her research vessel follows these guidelines, and as a consequence, her study is unable to address differences in impacts between kayaks and motorized vessels because the research platform is often too far away from the kayaks and the whales they are associated with.

A concern was raised regarding an apparent lack of a control data of killer whale behavior when vessels are not present. Dr. Bain replied it was difficult to get at this data but noted 25 out of 186 tracks were recorded in the absence of vessels. Dr. Noren commented that vessels are ever-present but added that she began her studies at 6:00 am in order to limit the boat numbers during some part of the study. She added the study was not intended to look at the effects of vessel presence versus absence but rather at the effects of varying numbers of vessels present and vessel distances from the killer whales. She further stated that how the number of vessels affects behavior is an important question. Dr. Ha added that Jennifer Marsh collected control data by conducting observations early in the morning, later in the evening, and during lunchtime when vessel presence was minimal but that data analysis still needed to be completed.

The question of killer whales' ability to become habituated to vessel presence over time was raised. Dr. Bain responded a characteristic of habituation is the presence of a static stimulus which does not change over time. He stated that vessel interactions are complex and unpredictable making it highly unlikely habituation has occurred.

When asked if he could be sure the observed changes in killer whales' direction are attributed to vessel presence Dr. Bain replied affirmatively and noted the study analyzed distributions of behavior. When asked if Southern Residents perform a suite of behaviors at the same rate in the presence and absence of vessels, Dr. Bain stated that results indicated a distinct difference between the two.

H. NOISE

Presentations[†]

- Brandon Southall, Office of Science and Technology, NMFS – Acoustic creatures in noisy environments: effects of sound on marine wildlife
- * John Hildebrand, Scripps Institution of Oceanography, University of California, San Diego – Ambient noise in the Haro Strait from whale watching and commercial vessels

[†] Only individuals presenting the papers are listed; please see the abstracts for a full list of authors.

* Indicates research wholly or partially funded by NOAA Fisheries.

- * Val Veirs, Colorado State – Average levels and power spectra of ambient sound in the habitat of Southern Resident orcas
- * Mike Wolfson, Applied Physics Laboratory, University of Washington – The acoustic environment of Haro Strait: A data-model comparison of shipping traffic noise
- * Andrew Foote, University of Durham – Acoustic studies of the Southern Resident killer whale population: implications for remote acoustic monitoring and indications of vocal behavioral change due to vessel noise

High Priority Research Question

- *Does vessel noise adversely affect Southern Resident killer whales?*

Noise Effects Discussion

1. What are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?
2. How can these results be used to inform the conservation of the Southern Resident killer whales?
3. Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?

Session Leader Summary (Leader: Dr. Brandon Southall)

Dr. Brandon Southall noted the impressive magnitude and breadth of data collected over the past three years in an effort to understand the baseline acoustic conditions in areas inhabited by Southern Resident killer whales, as well as variations attributable to natural and human factors, as a means of considering the potential effects of various noise sources (i.e., impacts). With respect to specific human sound source characterization, Dr. Southall was interested to learn of the spread of vessel noise into higher frequency ranges, and of vessels producing more noise when cruising than powering. He noted the strong degree of variation in noise over relatively small distances and the importance of characterizing both this and temporal variation. Overall, despite results demonstrating that types and uses of calls remain stable over time, the evidence of the change in duration of calls may indicate an effect on Southern Residents from increased noise levels, based on the results of Foote et al.

Presenter Responses to Participants' Questions

A participant stated although their initial assumption was high levels of noise would affect echolocation, results indicated low levels may have various effects as well. As such, they wondered if studies looked at the combined effect of low and high levels of noise on echolocation. Dr. John Hildebrand stated echolocation clicks are more stereotyped than social calls and may have potential for such an analysis. Dr. Hildebrand presented the analogy of listening to music in a car with the windows down; we adjust the volume of the music to compensate for the ambient noise from the open windows. Given the elevated state of ambient noise in Haro Strait, it seems plausible that certain exposures may affect echolocation in certain conditions. Dr. Southall stated that empirical in-vivo measurements of echolocation ranges for cetaceans are lacking, therefore it is difficult to measure impacts on these animals and/or their responses to such impacts.

Dr. Val Veirs suggested south-central Puget Sound is a very important location for killer whales from November to February. Research conducted in this area has been put on hold due to damage to acoustic gear during winter storms. He emphasized the importance of obtaining funding to continue such research and to share findings with the public and policy makers alike.

Dr. Linda Jones mentioned a contract was funded by the U.S. Navy in 2005 to compile a list of all existing data relative to Puget Sound ambient noise, however there was not a lot of information available.

Dr. Southall pointed to the importance of integrating passive acoustics into research efforts, as well as existing and planned ocean observing systems in a concerted manner and that NOAA was beginning to develop a plan to accomplish this in part. Public support must be enlisted to develop the necessary infrastructure and acquire sufficient funding to accomplish this task.

A participant noted that the Port of Vancouver is the largest port in Canada, Seattle is the third largest port in the U.S., that these existing ports will be expanded in the future, and new ports are being developed. Given this information he suggested it will be very important to continue monitoring vessel noise and to assess the impacts of the increased sound volume on killer whales.

A whale watch operator encouraged the consideration of idle speed alone when assessing impacts of noise on killer whales. He noted that the whale watch operators use idle speed when whales are present. Dr. Andrew Foote replied it is still worth measuring all aspects of noise even if idle speed was most common.

In response to a question of vessel noise affecting call intensity Dr. Foote said the observed changes in whale call duration may indicate a change in intensity as well. Dr. Veirs mentioned localization of source of calls is very difficult to assess but an on-going project is attempting to sort through data to determine if there are changes in source levels by call type. Dr. Southall confirmed he experienced this challenge while conducting a similar study with elephant seals even though the study was conducted on a beach where locations of the animals were known. He concluded the question was not trivial but that it was very difficult to answer.

A participant queried if study results could influence design of vessels and their propulsion systems. Dr. Southall responded that NOAA, the Marine Mammal Commission, the U.S. Navy and a number of industry partners hosted a meeting on the impacts of sound on marine mammals and the role industry might play in reworking their technology in 2004 (“Shipping Noise and Marine Mammals: A Forum for Science, Management and Technology” – information available at: www.shippingnoiseandmarinemammals.com). He added that a second meeting of the group is being scheduled for later this year or early next year, focusing specifically on a feasibility and economic analysis of applying vessel-quieting technology to large commercial vessels. Dr. Southall suggested there may be reasons for industry to explore new technology in the absence of regulatory enforcement, such as fuel-savings associated with increased efficiencies of improving existing technologies.

III. ROUNDTABLE PANEL SUMMARY

Panelists:

- Ken Balcomb, Center for Whale Research
- John Durban, Alaska Fisheries Science Center
- John Ford, Fisheries and Oceans Canada
- Brandon Southall, Office of Science and Technology, NMFS
- Laurie Weitkamp, Northwest Fisheries Science Center
- Judy Zeh, University of Washington

Session I Discussion Questions

- *After assessing all the information, what are the significant results in terms of answering the high priority research question(s) or in better understanding the population and its conservation?*
- *Can the risk factors that have been identified be ranked in terms of their impacts to the population?*
- *What are the potential interactions between risks factors?*
- *How can these results be used to inform the conservation of the Southern Resident killer whales?*

Session I Panelist Opening Comments

Roundtable panelists were invited to provide the Symposium participants with their thoughts in response to the Session I discussion questions based on their experience and the information presented during the Symposium.

Mr. Ken Balcomb expressed his delight at the extensive information presented throughout the Symposium regarding the basic biology and natural history of killer whales. He noted it is easy to be exclusionary within fields and disciplines but it is very important to move beyond this limiting perspective. Mr. Balcomb acknowledged Dr. Mike Bigg for instituting a collegial atmosphere of information sharing early in the study of Southern Residents adding that Dr. Bigg provided inspiration for this Symposium.

Mr. Balcomb summarized the following key messages:

- Although it is difficult to assess the winter range of killer whales we are beginning to discover some exciting information; it is unlikely anyone would have predicted the Southern Residents' range extends all the way to California 15 years ago.
- The detail available regarding habitat utilization demonstrates the relative importance of certain areas and identifies patterns of movement.
- Results of prey studies indicate a strong preference for Chinook salmon.

In closing, Mr. Balcomb expressed his belief that with continued research and collaboration, risk factors can be ranked and interactions between risk factors can be better understood.

Dr. John Durban identified session-specific highlights in response to Session I questions as follows:

- The ESA requirements of defining critical habitat, and determining the optimum population size present very difficult tasks due to key data gaps about year round distribution and historic population size. However, we have the benefit of 30 years of data to reference and provide context for on-going and future studies.
- The continuation of core photo-identification monitoring is critical, and this needs better funding support.
- A great deal is known about population dynamics thanks to long-term photo-id monitoring, and there is now strong evidence of a link between population dynamics and the abundance of preferred prey (Chinook salmon). This is a key research finding.
- We have found significant variability in social cohesion, which correlates also with Chinook salmon abundance. We need to understand better the link between social structure and population dynamics.
- We have learned a lot about contaminants from research focused on prey and surrogate species. Biopsy sampling on Southern Residents would provide a direct context for interpreting these findings, and should be carefully considered.
- The information conveyed during the Prey Session was very exciting. The concept of prey sharing by whales within groups can help us understand the consequences of social dynamics. Future research and analyses should look at prey quality, in addition to abundance, given the average size of Chinook is approximately half of what it used to be.
- Passive acoustic monitoring appears to be an effective means to better understand Southern Resident distribution during winter months. Killer whale recordings from initial deployments highlight the utility of this approach.
- Interactions between the various factors are important to understand. There is strong evidence that variation in Chinook salmon abundance and exposure to contaminants are significant risk factors. It is more uncertain to what extent vessel interactions impact killer whales but it is plausible that disturbance by vessels may interact with other risk factors, highlighting the importance of understanding the combined influence of risk factor interactions on killer whales.

Dr. John Ford acknowledged the valuable contributions of annual monitoring programs which have been maintained for decades without much financial support. These long term studies have become very important in interpreting trends observed in the Southern Resident population and have played a key role in conservation efforts for killer whales under Canada's Species at Risk Act (SARA) and the U.S. Endangered Species Act (ESA). Dr. Ford proposed the following ideas to consider when designing and/or expanding studies to tackle remaining questions:

- Killer whales are long lived animals, observable changes can occur gradually and responses to stimuli can be slow. Trends may take a long time to detect therefore we need to be patient in our attempts to draw conclusions.
- Some of the biggest advancements have been made in the field of population dynamics in determining what is driving population trends. These animals are slow to recover from mortality events but populations can decline quite rapidly.
- It is interesting to note that Northern Residents carry lower burdens of contaminants and experience less pressure from whale watching than Southern Residents, yet this population also suffered a significant decline during the mid/late 1990s for both populations. It seems likely that a wide-scale reduction in prey abundance, quality, or availability may have been the

primary factor driving the simultaneous declines seen in both northern and southern residents.

Dr. Brandon Southall provided the following summary of his perspective as an outsider to studies focused on killer whales:

- The results from population models indicate common forcing in mortality across pods. We need to look at what happened in the mid/late 1990s that was common to the Northern Residents and Southern Residents such as changes in Chinook abundance and quality.
- Dr. Bain's efforts to quantify effects of vessel proximity on killer whale foraging can help inform conservation efforts. Future studies should focus on whatever interferes with or inhibits the whales' ability to obtain (locate/track) prey.
- With respect to ranking risk factors, current chronic levels of noise exposure appear to be secondary to prey and contaminant issues. This situation may change as large vessel presence increases and a robust acoustic monitoring effort should be established to track impacts on foraging, energetics, etc. Research questions should focus on analyzing the ability of killer whales to forage on Chinook. The synergism issue of various risk factors will likely be most relevant to the study of energetics.

Dr. Laurie Weitkamp conveyed that her background is as a salmon biologist working specifically on the listing of Coho. Dr. Weitkamp stated it was impressive to see how much more we know about Southern Residents now than was known at the time of the previous workshops in 2003 and 2004. The body of evidence has grown significantly enhancing our understanding of this population. Dr. Weitkamp proposed consideration of the following when developing studies to assess the effects of changes in prey abundance and quality on killer whales:

- Chinook salmon catch has been declining for the past three decades due to concern for weak Chinook stocks. It was once three million, now it is one and a half million. Because fewer Chinook are being caught, more should be available for killer whales.
- A resurgence of many North Pacific marine populations (sardines, squid, etc.) has occurred over the last five to six years. Salmon trends likely reflect overall ocean productivity cycles; therefore strong correlations between killer whales and Chinook salmon may reflect both species responding to increased productivity, instead of Killer whales responding directly to Chinook salmon trends. It would be interesting to run killer whale population data against indicators of the relative productivity of the marine ecosystem as a whole, such as the Pacific Decadal Oscillation.
- If Southern Residents are fixating on Chinook salmon, you can make assumptions about Chinook spawning runs' influence on seasonal killer whale prey needs.
- Salmon catch has become highly regulated with ocean fisheries closed down this spring, and possibly for the summer and fall as well. Thus, the best data we have on salmon abundance and distribution is from the 1980's until 1995; current restrictions make it very difficult to gather new data.
- At this time we cannot accurately rank risk factors because we do not understand what is going on. The interactions between risk factors are complex but results from preliminary studies can help inform conservation when examined in an integrated fashion.
- Conservation efforts could include putting larger buffers around critical habitat areas, establishing a tougher approach to minimize release of contaminants, and increasing controls on salmon fisheries.

Dr. Judy Zeh introduced herself as a statistician from the University of Washington who has worked on bowhead whales for the International Whaling Commission. Dr. Zeh provided the following inventory of key insights gained during the Symposium:

- It is evident Chinook are incredibly important as preferred prey. Even if Chinook populations do not decrease, the size and quality of Chinook are important and should be taken into consideration.
- If the population viability analysis accurately indicates a current Puget Sound carrying capacity of 100 killer whales, there is a real risk of extinction in the relatively near future.
- It is futile to concern ourselves with determining the historical carrying capacity of Puget Sound as current conditions do not relate to what conditions were in the past. Instead efforts should focus on continuing to monitor the current Southern Resident population size.
- Given the notion that the blocks of good years are getting shorter and blocks of bad years getting longer, consider studying the ecosystem as a whole and the effects of global warming.
- Vessel disturbance and noise effects are important factors if they decrease foraging/feeding ability, especially if the Chinook habitat is increasingly disturbed and their quality becomes further diminished.

Session I Full Symposium Discussion

At this time panelists were encouraged to respond to each others' perspectives, and comments and questions from Symposium attendees were encouraged as well.

Dr. Durban added that more consideration should be given to killer whales from an ecosystem perspective. Attention should be devoted to an expanded perspective when considering management goals as there are interactions between and within multiple trophic levels

Dr. Dawn Noren observed that several significant results were presented during the Symposium, including the premise of Northern Residents' decline not being as intense as the Southern Residents' decline. She added that the difference in decline may be due to other confounding factors and therefore comparisons between populations are critical.

Dr. John Calambokidis stated that the most compelling factor was the killer whale prey preference for Chinook salmon. Given his experience with harbor seals in Puget Sound, evidence suggests contaminants like polychlorinated biphenyls (PCBs) have a legacy of successive stages of effects on reproduction and immunosuppression; beginning in the 1960s and 1970s and persisting through modern times. We need to consider historical trends, especially for Transients, on a long-term scale to accurately depict contaminants' impact on killer whales. Although prey appears to be the major factor contributing to current impacts, legacy effects from contaminants are also significantly affecting them now. He felt that management efforts should focus on Chinook and prey issues and research dollars should be dedicated to addressing the largest data gaps such as impacts of contaminants and vessel interactions.

Dr. Samuel Wasser suggested most Southern Resident deaths occur during winter months, and proposed this timing is extremely important to keep in mind when discussing causality. It is

important to know how healthy the animals are when they leave for the winter as they are less likely to survive the winter months if they are already unhealthy in the fall.

Mr. Balcomb replied mortalities have been documented when whales return in the summer months, validating the assumption deaths usually occur between October and their return. An anomaly to this trend occurred throughout 1994-1997 when whales died off during the summer months and photo identification records indicated occurrences of 'peanut head' (a depression behind the head attributed to nutritional stress). Photo identification can be used to provide an objective way of examining body condition at the beginning, middle and end of the whale watching season. Dr. Wasser added thyroid hormone levels in a sample from the wild population were $\frac{1}{4}$ the concentration found in captive whales, suggesting that wild whales are very undernourished.

Dr. Peter Olesiuk proposed further research be conducted to elaborate on the relationship between Chinook abundance and mortality rates. Analyses conducted to date show that the inverse relationship between Southern and Northern Resident mortality rates and Chinook abundance is strongest with total Chinook abundance over the entire range of these populations, rather than local Chinook abundance in core areas. Dr. Olesiuk does not believe Chinook abundance in local core areas during summer represents the bottleneck that appears to be affecting killer whale mortality during winter months. Rather, it is important to 1) further explore the relationship between winter Chinook abundance and extent of killer whale ranges; and 2) identify if there are other prey species besides Chinook being utilized during the winter.

Dr. Durban pointed out calving seasonality does not appear to coincide with our perceived idea of key summer feeding times, and that core areas may be perceived as core to researchers, but may not be perceived as core to whales.

An audience member commented that a key area in need of more study is south Puget Sound, from November through February, where there has been a dramatic increase in chum populations over the past few years. She added that we should not paint too broad a picture about killer whale dependence on Chinook as chum runs through winter months may be as important as Chinook are in the summer.

Dr. Weitkamp agreed chum runs have been increasing for several years and added salmon quality has been decreasing over time. She raised the question of whether killer whales behave like grizzly bears by gorging themselves to prepare for winter months and wondered if their feeding behavior is different at the beginning of spring when they return to core areas.

Fred Felleman suggested births could be triggered by sufficient banking of blubber to sustain calving and nursing. He proposed killer whales may depend on spring Chinook to recover and wondered why killer whales would lactate during periods of decline in prey availability. In response Mr. Balcomb provided an overview of birthing trends, stating mating historically occurred during the summer with births in winter following after 17 months of gestation. Upon return from winter calving and nursing, the whales were able to feed heavily on Puget Sound spring Chinook runs. In the recent past summer births were observed indicating the possibility pods congregate and mate during the winter too.

Dr. Noren remarked upon the importance of salmon as prey but added stomach contents suggest killer whales also feed on squid and other fish species. She indicated it is critical to address the major data gaps regarding winter prey preferences which could be accomplished by analyzing biopsy samples. Dr. Durban replied that chemical analyses of biopsy samples from studies of Transients in Alaska are beginning to show seasonal shifts in diet and suggested that data gaps on seasonal variability of Southern Resident diet could be addressed in this way.

Dr. Wasser indicated the critical time for mortality in many offspring often occurs during the weaning phase. Young juveniles need food that is readily available and easy to digest, which is validated by observations of juveniles feeding on pinks. It is important to assess the health of killer whales before they leave for the winter but also to know that newborns are at risk while being weaned. Dr. Ford suggested food sharing behavior may not leave weaning juveniles quite so vulnerable. He added that the temporal aspect of reproduction is influential, with summer providing inter-pod breeding opportunities. An audience member offered that gestation is a minor drain on marine mammals, while lactation significantly depletes the mothers' energy reserves.

Dr. David Bain expressed his interest in population viability analysis (PVA) being used to estimate the current carrying capacity of Puget Sound. If the results of this model estimated a carrying capacity of 100 Southern Residents it would indicate a substantial risk of extinction for these animals. It could also be used to assess whether the historical population was significantly greater than the current population to assist in establishing goals for conservation. An increasing population preserves genetic diversity which is critical to preventing the loss of animals to disease. With respect to the relative ranking of risk factors, Dr. Bain identified the following factors as being noteworthy:

- The demonstrated prey preference for Chinook salmon indicates rebuilding Chinook stocks could be an important component of Southern Resident population recovery efforts. If we are not successful in population recovery efforts the magnitude of current and increasing levels of impacts on a declining population will be severe.
- More boats are entering the picture as more people enjoy whale watching; seemingly small impacts now may increase over time.
- The introduction of emerging toxins into the marine environment such as polybrominated diphenyl ether (PBDEs) is increasing very rapidly. It may be years later before we realize we should have done something to control these new toxins.
- Disease has been a virtually unexplored area. Because small populations are more vulnerable to disease we should consider the potential for future outbreaks and how to prevent or contain them.
- Oil spills are a risk factor not discussed during the Symposium, yet there is an increasing amount of oil coming into Washington.

Dr. Bain concluded his comments by stating we have the ability to conduct retrospective analyses, but we need to anticipate emerging factors which have not been significant in the past but may be more important in the future.

Dr. Linda Jones emphasized the importance of utilizing an ecosystem approach to inform future management and conservation strategies. Current efforts are beginning to incorporate this approach while looking at killer whales and their prey, but it can be further expanded to consider environmental factors and the effects of global warming as well.

An audience member pointed out the dilemma faced when striving to balance management actions for endangered and threatened salmon with actions for Southern Residents. If hatchery fish production is ramped down to help wild salmon stocks the reduction in prey could significantly impact killer whales. Inversely, if hatchery production is sustained or increased to support killer whales the native fish could suffer.

Dr. Weitkamp queried if the carrying capacity of the North Pacific Ocean is being exceeded by the magnitude of hatchery fish production, using Japan's production of chum and pink salmon as an example. Exceeding carrying capacity significantly increases the need for wild fish stocks to compete for available food.

Shane Aggregard noted hatchery programs in Washington are very successful at producing chums and pinks but Chinook production is more difficult. He asked if there was any talk of hatchery goals shifting the emphasis to Chinook production given the killer whales' preference for prey. Dr. Weitkamp replied pink and chum production is easy and cost-effective as the turn-around time between egg production and release is very short. Chinook and Coho are much more expensive to produce with fall Chinook reared for a few months and Spring Chinook and Coho reared for up to a year. It may be appropriate to consider shifting some resources from Coho to Chinook production, but a more effective strategy of focusing on Chinook habitat restoration would provide longer-term benefits.

An audience member commented on the effective population of Southern Residents, observing that with only 1/3 of the current population of 85 animals being of a reproductive age, the effective population is limited to 30 or fewer killer whales. Mr. Balcomb concurred and restated the importance of salmon in recovery programs. Hatchery production can provide short-term benefits but a long term solution lies in restoring the natural environment to the greatest extent possible

Dr. Durban commented that published data suggests that Southern Residents are not diving as deeply in recent years and wondered if this is because they are feeding on hatchery fish which tend to occupy shallower depths in the water column than native fish.. Dr. Brad Hanson replied it may be related to their ability to catch fish but study results are not conclusive. It is possible killer whales have been diving more frequently because they were having trouble locating prey.

An audience member contended salmon found near Vancouver Island are larger due to different feeding habits and occupying different levels of the water column. They posed the question of whether management efforts were focused on improving water quality in the South Puget Sound to improve habitat for salmon. Dr. Weitkamp replied oysters and shellfish culture are used as "canaries" and drive water quality clean up efforts; if water quality is good enough for the oysters it is good enough for the salmon.

An audience member stated that progress is being made to reduce impacts of contaminants on salmon and suggested toxic clean up efforts, at for example Superfund sites, are more cost-effective than direct efforts to increase salmon populations.

Session II Discussion Questions

- *What are the highest priorities for future research?*
- *Are there critical information gaps that still need to be addressed for conservation? If so, what are they? What method(s) is most likely to successfully address the gap taking into account biases and cost and logistical limitations?*

Roundtable panelists were invited to provide the Symposium participants with their thoughts in response to the Session II discussion questions based on their experience and the information presented during the Symposium.

Dr. John Ford proposed predictable, adequate funding needs to be secured to maintain the long-term photo identification program. Addressing data gaps is a critical priority for future research which should focus on the following:

- Distribution, behavior, and preferred prey of killer whales during the winter months of December through April. We know the Southern Residents' range extends all along the west coast with infrequent visits to their summer and fall range(s). Acoustic monitoring appears to be a promising technique to gather data via an expanded network of stations along the coast. In addition to providing recorded data, an acoustic alert of the whales' presence could be transmitted to researchers interested in conducting field observations. While satellite tagging has not been attempted in this region it shows some promise. Attachment systems should be perfected on other less sensitive populations before being applied to Southern Residents.
- There is a need to better understand the killer whales' prey itself as winter data are also lacking for prey. A great challenge is presented by the 'black box' of ocean survival, as we do not know what happens to salmon before they return to spawn. Additionally, more information is needed to describe predator-prey interactions and the influence of prey behavior.
- Proximate causes of nutritional stress (e.g., disease) are difficult to study but are very important considerations.
- Comparative studies of population dynamics between different pods in different regions would be useful.
- With respect to impacts of noise, the effects of ambient noise on echolocation and the development of vessel drive systems which minimize noise production warrant further investments.

Dr. Weitkamp suggested research focus on the following priorities to address critical data gaps:

- Acquiring sufficient information on winter distribution to draw a map similar to the map of core summer areas.
- Determining the historic population size and distribution to determine recovery goals.
- Contaminants could affect fecundity yet the fecundity of Northern Residents and Southern Residents did not differ significantly even though the concentrations of contaminants found in each population are very different. Comparison studies should examine Transients for higher concentrations and Alaska/Arctic populations for lower concentrations of contaminants.
- The analysis of prey quality and quantity should focus on how many fish they need to eat and comparing that to the number of fish available.
- Determining if feeding patterns are constant throughout the year or if killer whales gorge themselves at certain times.

- It is important to provide some context for what is ‘normal’ for killer whales. Where are Southern Residents within the range of variability?
- Although satellite tagging of Chinook and other salmon is challenging due to juveniles being too small and the recovery rate for acoustic tags being not very high, researchers are working hard to address these issues.

Dr. Southall stressed the importance of integrating multi-use applications of research to address synergism issues and budget constraints. Insight into complex risk factor interactions can be gained with simultaneous measurements and funding can be more readily secured for efforts which serve multiple functions. Dr. Southall summarized passive acoustic monitoring being most useful when used as a tool to:

- Identify Southern Residents’ winter habitat and distribution.
- Identify ambient noise budgets.
- Gather information on climate.
- Educate the public and share information (as proposed by Dr. Val Veirs).

Additionally Dr. Southall suggested there is a need for real time data using radio telemetry but added that fixed systems with on-board data storage are more applicable here. He also proposed future acoustic studies should 1) focus on the echolocation behavior of animals in the field for evaluating foraging; and 2) establish baseline behaviors and signal characteristics of animals to assess how they change in varying noise conditions. A tool to establish such baselines could involve the use of play backs to tease apart the various signals. Not much is known about stress and non-auditory effects from noise but it could be evaluated by comparing stress-related hormones levels in captive and wild animals. Finally, Dr. Southall proposed we be prepared for anomalous conditions as they provide unexpected opportunities to learn even when the conditions are harmful to the animals; we cannot return to primordial noise levels.

Dr. Durban stated research priorities should maintain an awareness of the body of evidence gleaned from long term research when pursuing new focus areas. He indicated that maintaining existing time series, particularly photo-identification data, prey sampling and acoustic recordings, should remain the highest priority. Much of the data supporting the ESA listing came from these core-long term studies, particularly photo-identification monitoring of this population. These valuable studies need to be continued. New studies can then build on these key time series, and should focus on the following parameters:

- Passive acoustics to monitor winter distribution
- A quantitative, model-based framework to integrate data as it is collected would help to facilitate our understanding of interactions within this marine ecosystem, and would allow updating inference as datasets develop.

He closed by suggesting that more invasive techniques, specifically biopsy sampling and satellite tagging, may help to fill data gaps. However, their use needs to be thoughtfully considered and discussed before implementation. Also, it is important to avoid duplication of effort, given funding scarcities.

Mr. Balcomb agreed photo identification surveys should be continued in the future. He then proposed the following priorities for future research:

- Identifying Southern Resident winter distribution outside of the core Puget Sound areas.
- The existing public sighting system to track whales during the winter months has been fairly cost effective to develop and implement and should be continued.
- Assess killer whales' prey demand (# of fish/animal/day) and compare that to prey abundance and distribution, in consultation with fisheries biologists.
- The development of sound surveillance systems from the 1970s indicates the ocean's ambient noise is increasing. Passive acoustic monitoring of whale and vessel sounds is important given beaked whale and other sensitive species behavior indicates a threat of potentially lethal impacts in response to noise (e.g., the Shoup incident). It could be cost effective to establish passive systems in as much of the habitat as possible and a real time set up would be optimal.
- Cultural dynamics should be considered as well.

Session II Full Symposium Discussion

At this time panelists were encouraged to respond to each others' perspectives, and comments and questions from the Symposium attendees were encouraged as well.

Howard Garrett stated there is a need to understand killer whale social dynamics better than we do, especially with respect to prey sharing behavior and how it influences survivability. He posited that the preference for Chinook can only be explained by a cultural hypothesis requiring a level of interdisciplinary research never attempted before. Killer whales have a culture without parallel except in humans and should not be studied within the same parameters we establish for other marine mammals in terms of interpreting behavior. Mr. Garrett inquired if anyone intended to consult with social scientists. He proposed research focus on identifying the hot spots for feeding instead of looking at availability of prey.

Mr. Balcomb replied it is known killer whales are a distinct species and that they are ours to keep or lose. Dr. Durban agreed and stated Canada's SARA includes management goals to maintain the cultural continuity of northern and southern resident killer whales. He added that we need to have continuity in research methods by ensuring that researchers are consistently trained in observation techniques to ensure continuity in identification of cultural-specific behaviors.

Mr. Felleman noted we do not manage whales; we manage people. He stressed the relevance of this perspective given bilateral management efforts of the U.S. and Canada and suggested these efforts should be closely synchronized in future recovery planning. It is remarkable what management practices can accomplish when it is an 'important' resource (e.g., halibut and salmon).

Mr. Felleman noted a lack of oceanography information throughout the Symposium and proposed El Niño, and other big ocean forcing mechanisms/shifts in upwelling be considered in future efforts to determine impacts on Southern Residents. Given that the first decline in populations is perfectly paired with the occurrence of El Niño, he suggested future data management apply an oceanographic filter to future analyses.

Mr. Felleman concluded his comments stating the Navy has gotten off the hook with respect to sonar testing and its impacts on marine mammals. He noted the U.S. has the third largest naval complex in the world in Puget Sound and suggested the Navy has an obligation to use their acoustic

prowess to contribute to research efforts and to assess whether or not the whales are around before conducting sonar testing. In response, Mr. Balcomb recognized that the acoustic systems available to the military are phenomenal and suggested their assistance in monitoring Southern Residents be sought.

Dr. Jim Ha stated his work at the University of Washington focuses on animal behavior and his field of expertise is in social behavior of highly cognitive animals. He noted the extensive amount of research conducted in the past three years and amount of new information available as a result of the Congressional funding. He indicated research should balance biological and social/cultural assessments given evidence indicating killer whale populations may follow Chinook cycles, which may follow global climate cycles. Dr. Ha noted the population decreases were more dramatic in Southern Residents than Northern Residents due to the combination and interaction of risk factors. The impacts of various risk factors such as vessels and noise result in less foraging behavior and leave fewer opportunities for social and cultural interactions. He commented that the extent of prey sharing behavior has come to light as a result of focal whale/group studies and may help them get through very difficult times such as weaning offspring.

Dr. Wasser commented on the confounding observations that 1) neither males nor females disperse from their natal group although the biological pressure to disperse must be enormous; and 2) that residents and Transients inhabit the same coastal waters but they never mate with each other. Given the presence of male hormones it is astounding they do not leave to mate with another group. Perhaps a great pressure between the groups exists and Southern Resident males remain with their natal group to protect the females from Transients.

Dr. Wasser also pointed out radio telemetry technology is becoming microscopic; researchers have been putting radio transmitters on dragonflies and developing transmitters to track them. Less invasive technology for tracking animals is available and, he suggested, could be utilized to identify winter ranges.

Dr. Michael Ford stated the most interesting result is the correlation in mortality between different pods suggesting some form of universal forcing. It is important to understand what is causing similarities and differences between pods to get a handle on why Southern Residents in general, and some pods within the Southern Resident population in particular, are experiencing a greater magnitude of impact. Dr. Ford added that we need to learn more about the paternal family structure of these whales, the mating patterns within Southern Residents, and occurrences of cross-breeding with other groups such as Transients to potentially confirm results of gene flow studies. An audience member questioned the plausibility of Southern Residents interbreeding with Transients, recalling an incident when Transients were attacked by J-Pod and pushed into the shoreline. This behavior was confirmed by another audience member; adding both males and females have participated in chasing Transients off. The participation of the SRKW pod(s) as a whole in these attacks raises questions as to whether or not SRKW males remain with their natal groups to provide females protection from Transients.

Education was emphasized as a means to engage support for future conservation efforts. The media can provide a great deal of help when science has clearly defined needs. Science in and of itself is a

tremendous tool, but education and media allow us to connect to the public and provide common ground for the conservation of killer whales.

Dr. Pete Schroeder agreed and commented that when one of the whales dies, it is a newsworthy event. He noted a paradigm exists for killer whales' susceptibility to disease but we should consider the health of individual animals. The basis for longevity is good nutrition, which begins in the post-natal period. Young juveniles need to wean within a good nutritional environment but the health of the nutritional environment is changing and poor nutrition is being amplified by other stressors. The killer whales represent a unique social group, reinforced by synchronous breathing, prey sharing and other behaviors which create a cohesive pod identity. Also, this social behavior provides a vector type of environment for disease epidemics and increases a population's susceptibility to a catastrophic disease event. Research should include environmental bacterial flora through micro layer definition – air water interface and source analysis of coliforms and bacterial analysis of normal blowhole microflora through blowhole sample collection. Bacteria in the micro layer can adapt to living in the saltwater environment; when an immuno-compromised animal travels to the warmer waters of California they become more susceptible to disease. We should retrospectively review mortalities which occurred between 1995 and 2001 and look for signs of malnutrition using photo identifications. He concluded we will never be able to recover the population to the numbers which existed in the past, so a realistic goal for management should be established.

Dr. Dave Bain shared his opinion on priority research areas and critical data gaps as follows:

- Need to know more about their year-round range; where they are going and what they are doing there.
- Need to know what they are feeding on and what their social groups are.
- Baseline data is invaluable.
 - Need baseline data for demographics.
 - Long term records exist to establish baseline data on varieties of prey.
 - Review calibrated recordings to look at what noise was like 20 years ago to establish a baseline.
 - Create a baseline for disease using existing necropsy data detailing presence of pathogens and seek out recently dead killer whales to get more data rather than lose this information forever.
- Research on sociology may indicate paternal care is necessary for survival.
- Strive to understand the world from the killer whales' perspective to better understand implications of: prey preferences (limited abundance and availability of four-year old Chinook), impacts of noise (within the range of their detection frequencies), and avoidance of abundant and available prey (possibly due to relative energetic costs of foraging for different species, species-specific parasites, and/or cultural transmissions).
- Many statistically insignificant changes exist which may have biological significance.
- As killer whale sounds can be detected for several miles, real time acoustic data can be collected and analyzed now instead of waiting for less invasive tracking technology to be developed.
- Consider plasticity in echolocation.
- Establish a baseline historical definition of 'quiet'.

An audience member expressed the opinion that research should focus on core critical habitat in Puget Sound, and use non-invasive and passive research techniques to avoid becoming part of the problem.

Dr. Rus Hoelzel proposed looking at patriline markers (e.g., Y chromosomes) to compare with matriline markers and suggested we not be timid in assuming there is no genetic variation through mating movements. Female genetic markers indicate they do not leave their pods to mate, but we should not assume the same for males. While males do not physically disperse from their pods it is possible their genes have opportunities to migrate.

Attention was turned to surface feeding activities with an audience member describing an incident of killer whales taking a sea lion and then playing with it. It was suggested multiple observed surface behavior events involving Chinook could have been attributed to one fish. It is possible Chinook handling occurs at the surface a lot, but there could be significant feeding occurring beneath the surface that we never see.

Dr. Zeh commented on the importance of analyzing all data that have been collected, and proposed mixing models and enlisting statisticians to generate innovative ideas to get more out of the data. Dr. Zeh noted the importance of training young scientists to become proficient in photo identification to maintain and ensure consistency in this useful research tool.

Dr. Southall shared his appreciation for the enthusiasm surrounding the application of passive acoustics in research but warned of the bounds of real time systems and autonomous deployments and the trade-offs between them; these trade-offs, including bandwidths and cost, must be considered to make good decisions.

An audience member noted an extensive data set on Chinook exists to be gleaned for information; we just need to identify the right questions and ask the right people. Acoustic technology is already being applied to studying fish stock movements. Tags have been inserted in ling cod, Coho yearlings, Chinook, and cutthroat trout with information transmitted to an array of 17 different receivers located south of the Narrows Bridge.

Mr. Aggregard emphasized the benefit of educating the public to possibly influence legislation. Whale watching in general has been perceived as having a negative impact on killer whales, but it is important to understand the potential benefits whale watching excursions provide by educating the public. Over the course of one season one naturalist can lead 500 trips; educating approximately 20,000 people. Mr. Aggregard requested scientists keep in mind the industry is willing and eager to help with research in any way possible. His company has worked with the Center for Whale Research and Cascadia Research Collective in the past and he put forth a standing invitation to have scientists on his boats at no cost.

Robin Dunkin asked the group if anyone was looking at activity budgets of Alaska residents versus Southern Residents, or if there were any plans to do so. Dr. Durban replied it was a great idea but was not aware of any such research projects. He added that the link between killer whale population dynamics, prey abundance and oceanic conditions would be easier to evaluate if studies were

extended to include Southeast Alaskan residents, and suggested using a comparative methodology including Northern and Southern Residents, and possibly other populations in Alaska.

Symposium Closing

Members of the Symposium Planning Committee were asked if they had any final comments to offer in closing. Rocky Beach thanked everyone for attending the Symposium. He stated plenty of opportunities are available for future research and proposed the WDFW could possibly access funding and resources from their fish division to help with killer whale studies. Mr. Beach encouraged the group to consider all the data available and to continue thinking outside the box.

Dr. Michael Ford also expressed his thanks to everyone who attended the Symposium. He stated he learned a tremendous amount as someone who has not been studying killer whales in particular for very long. Dr. Ford thanked the presenters and panelists for sharing valuable information and insight. He also thanked Christel Martin, Linda Jones, and the Planning Committee as a whole for all their efforts.

Dr. Linda Jones added her thanks to all the presenters and participants for their valuable contributions to the Symposium. She concluded by stating that these collective contributions showcased how much research is being done and highlighted opportunities for future collaborative studies.